

Nanostructured Materials

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ICASE/USRA/LaRC Workshop: Revolutionary Aerospace Systems
Concepts for Human/Robotic Exploration of the Solar System
Hampton, Virginia

7 November 2001

*materials are needed to make
anything in technology...*

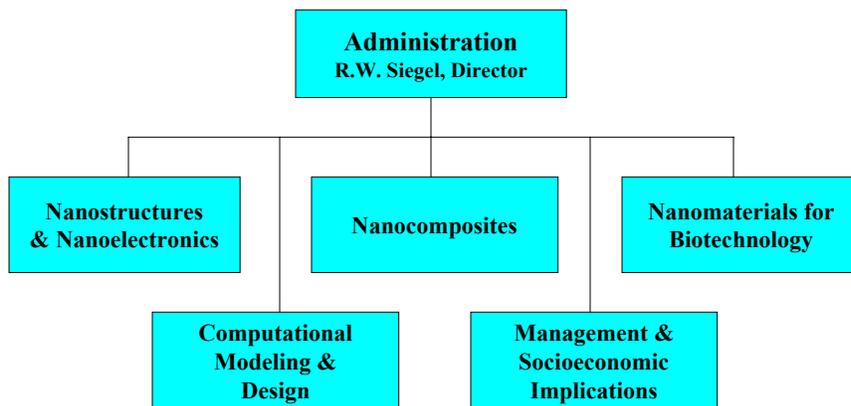
*nanomaterials are needed to make
anything in nanotechnology*



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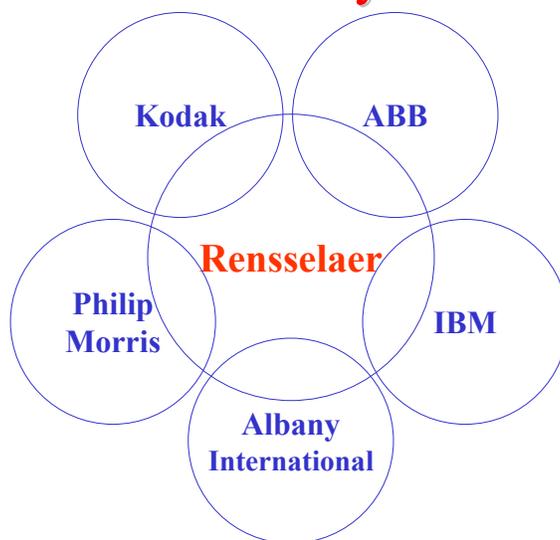
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Rensselaer-Industry Partnership



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National Science Foundation



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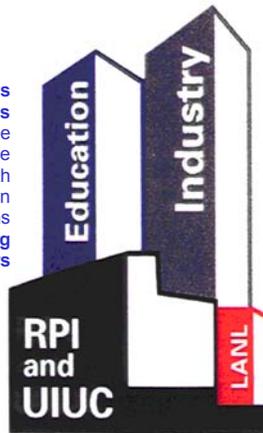


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Nanoscale Science and Engineering Center

K-12 Programs
Undergraduate Colleges
Morehouse
Mount Holyoke
Smith
Spelman
Williams
Distance-learning
Visiting Researchers



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University of Illinois
at Urbana-Champaign

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Albany International
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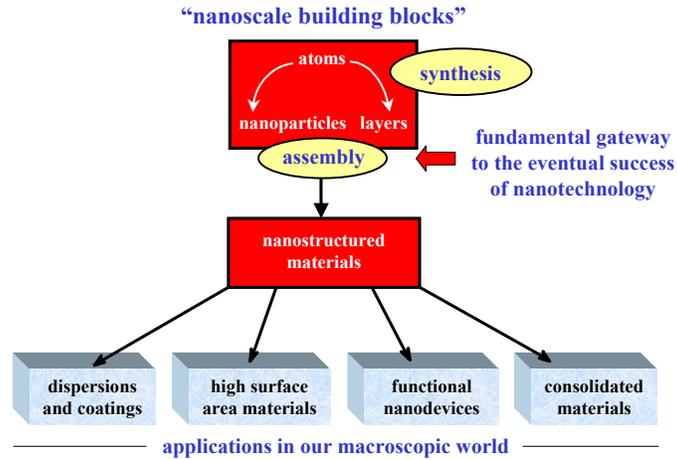
NSF Center for Directed Assembly of Nanostructures



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...from atoms to applications through nanoscience

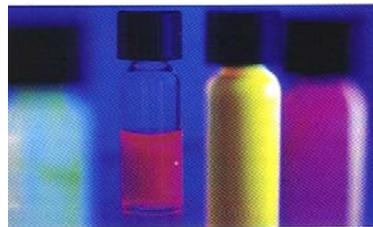


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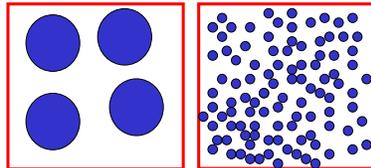
What is special about nanoscale building blocks?

➤ Size confinement



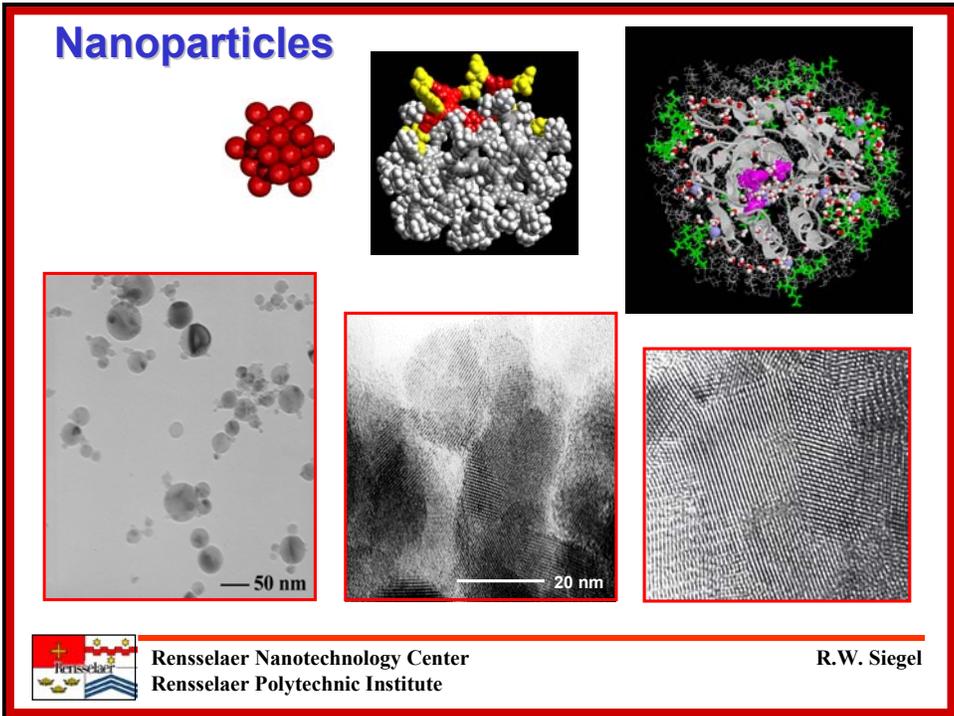
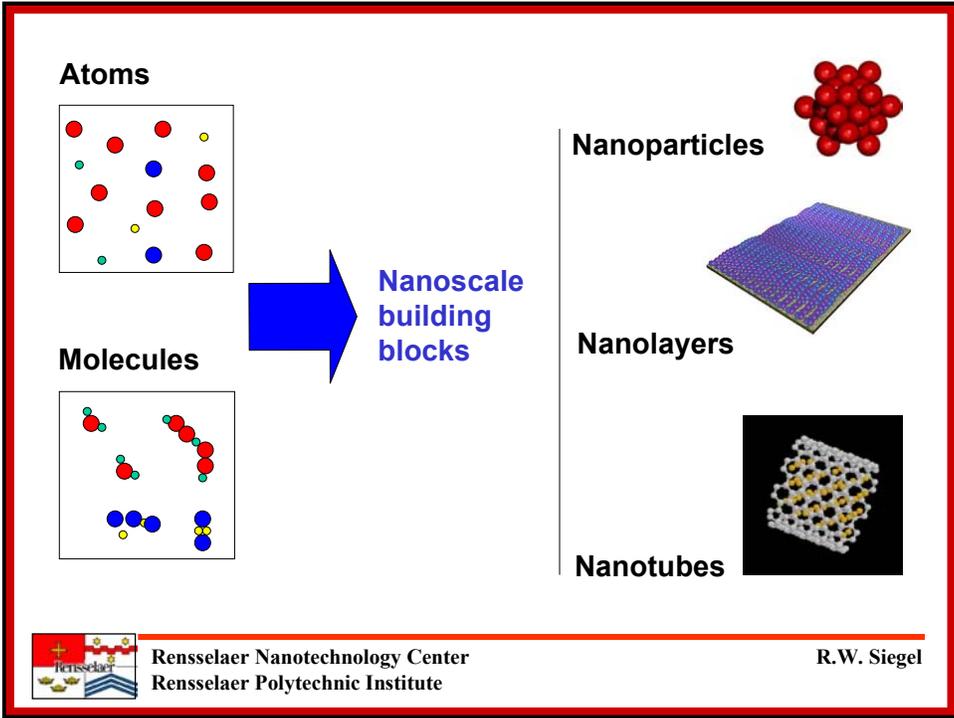
➤ High surface area

➤ Many interfaces

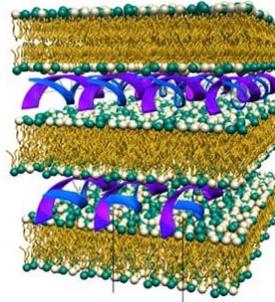
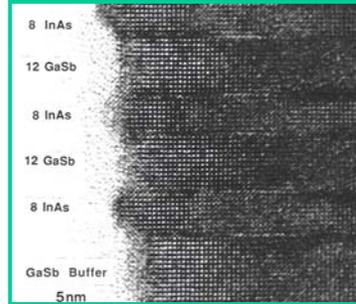
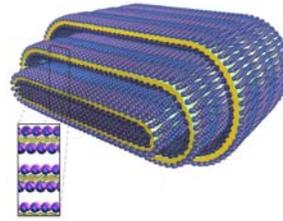
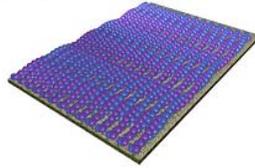


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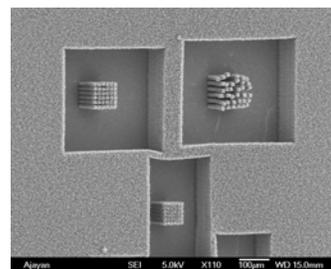
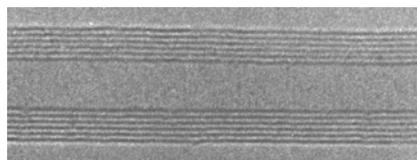
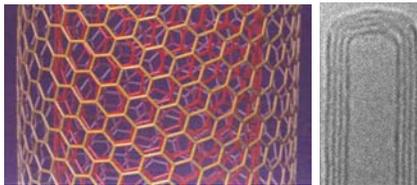
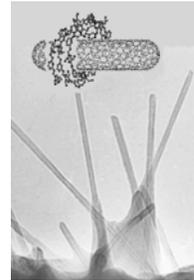
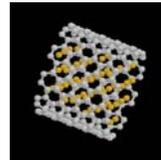
Nanolayers



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Nanotubes



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Issues in nanostructuring

➤ **Building blocks**

- Size scale
- Chemical composition

➤ **Assembly**

- Interfaces and interactions
- Modulation dimensionality
- Architecture and hierarchy

➤ **Function**

- Properties



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Characteristics of nanostructured materials and assemblies

- **Small**
- **Lightweight**
- **Novel properties**
- **Multifunctional**
- **Hierarchical**
- **Smart**

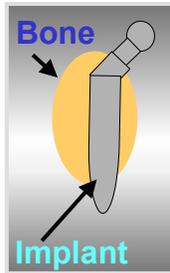
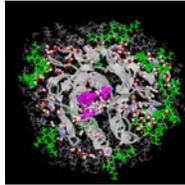


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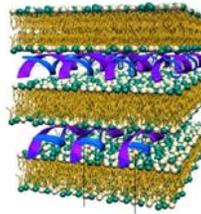
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Application Areas

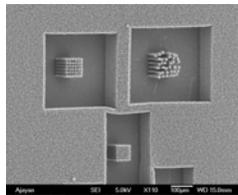
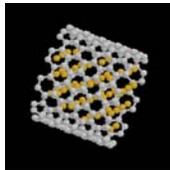
Health



Environment



Communication



Manufacturing



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Examples of Opportunities for Nanomaterials

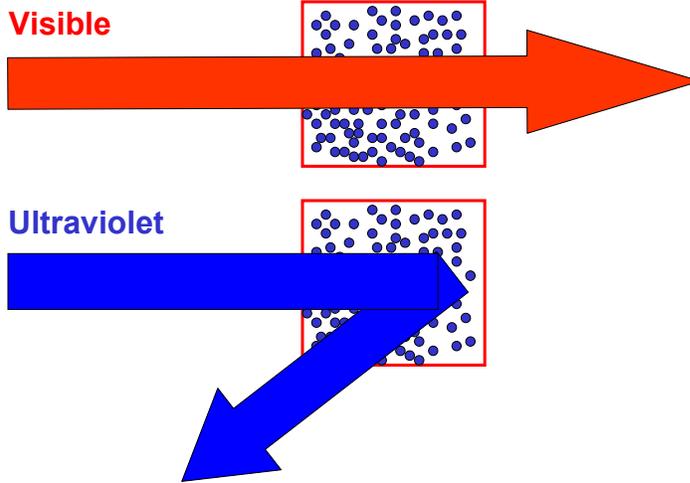
- Thermal and environmental barriers
- Wear resistant coatings and parts
- Tailored optical and chemical barriers
- Flame retardant plastics
- High capacity energy and information storage media
- Drug and food supplement delivery vehicles
- Ultrahigh-strength, tough structural materials
- Net-shape formed ceramic parts
- Magnetic/thermoelectric thermal management devices
- Smart materials with embedded sensors and actuators
- Biomaterials



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Protection from ultraviolet radiation

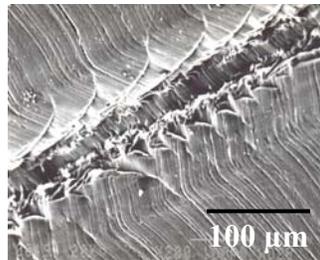


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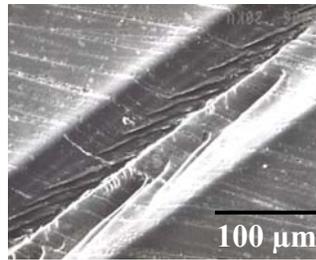
Scratch resistance of nanoparticle filled polymers (plastics)

Epoxy



Scratch depth 44 microns

with 10 wt% nano-TiO₂



Scratch depth 28 microns

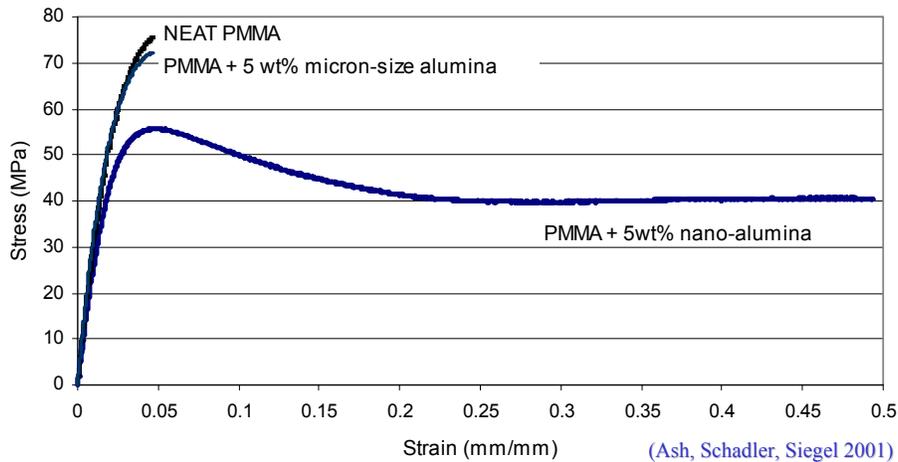
(Ng, Schadler, Siegel 2000)



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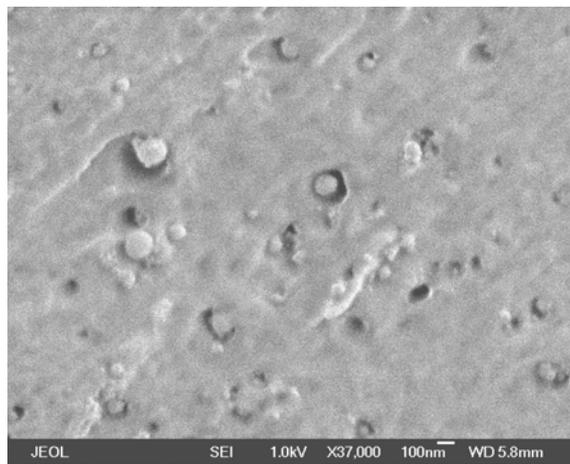
Comparison between Micron-size and Nanoscale Alumina Fillers in PMMA



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PMMA/Coated Al₂O₃ Composite Fracture Surface

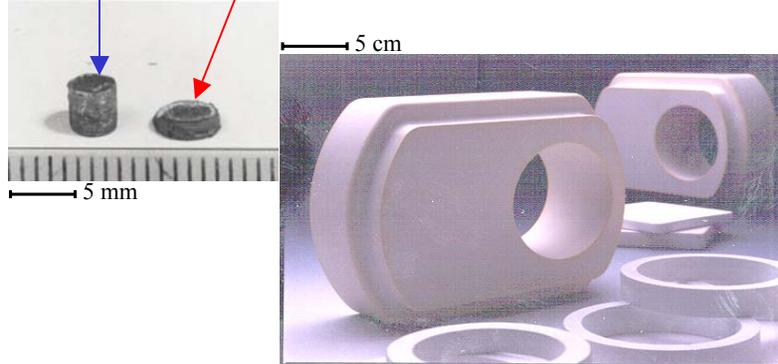


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Net-shape forming of ceramics

before and after
hot compression



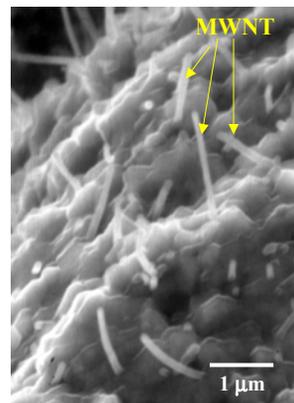
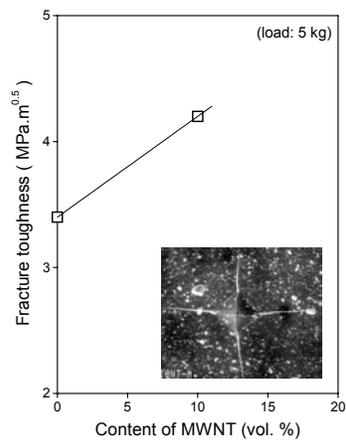
Nanophase Technologies Corporation



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Fracture Toughness: MWNT / Alumina



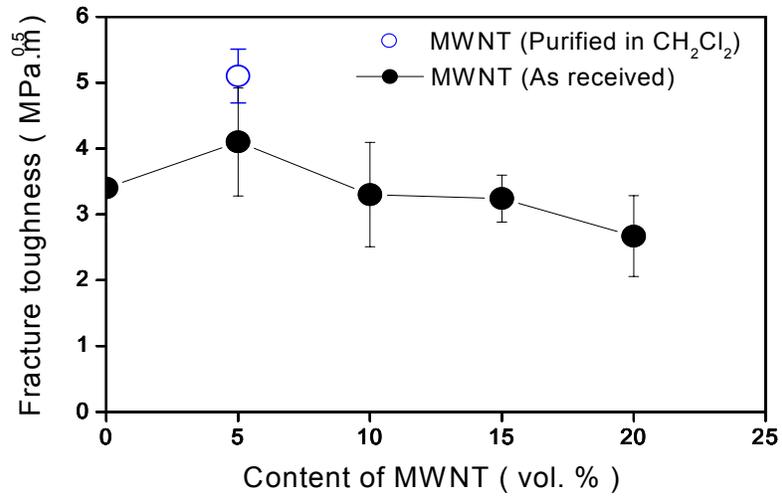
(Chang, Doremus, Ajayan, Siegel 2000)



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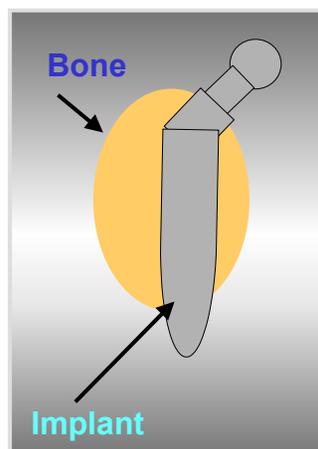
Fracture Toughness of Nanophase Alumina/MWNT Composites



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Bone replacement



Implant requirements:

- mechanical behavior close to that of bone
- cellular compatibility
- osseointegration

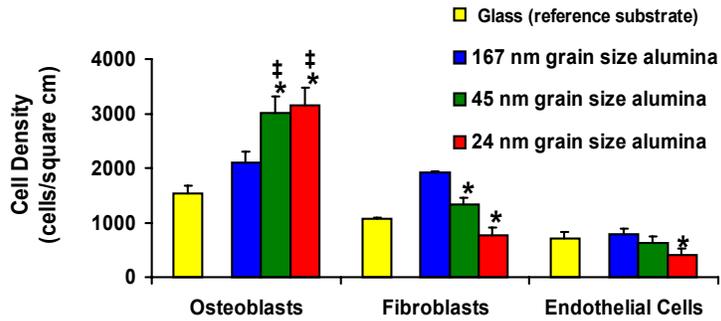
(Webster, Siegel, Bizios 2000)



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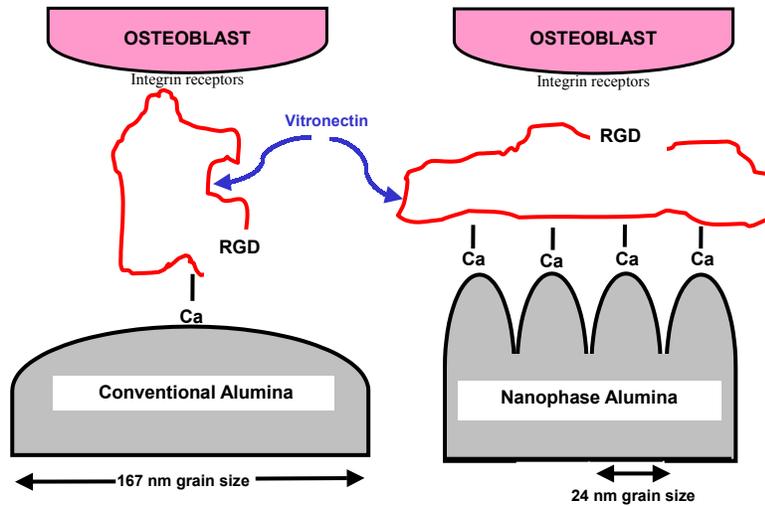
Cellular compatability



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Osteoblast adhesion



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Conclusions:

- **We are now able to create a wide variety of nanoscale building blocks**
- **We are learning how to assemble them into useful nanostructured materials and devices**
- **Society is beginning to benefit from nanoscience and its applications**
- **There is much more to come....!**



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